CEC A/V Project
Existing Product Assessment and Conclusions Memo

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Re: Existing Product Assessment and Conclusions

This memo is the first deliverable for Task 2.11 on "A/V Control" of the LBNL Energy Efficiency Research Projects that began in 2011 (full title of 2.11 is "Improved Audio-Video Efficiency through Inter-Device Control"). It is an informal memo summarizing findings and conclusions to date about features and capabilities found in existing products. A companion to this is the recently-completed paper for the ACEEE Summer Study[1]; that is not a specific deliverable for this project but has valuable background for this memo, including explaining key concepts underlying how A/V systems work in ways which affect their energy use. It also shows the directions that the later phases of this project will be heading, focusing on power states, how states change, characteristics of particular communications technologies, and user interface issues.

In our approach, we considered gathering data about products from assessing them in the field (in people's houses), in stores, and from examining operation manuals. We found the most useful information in manuals and the least in stores. Examining actual collections of devices in the field showed the types of connections in actual use (since they have many more interfaces than needed or typically used), and the types of devices typically found with each other. User manuals often contain much information that would be difficult or impossible to determine through other means. We did use on-line stores as a way to select product models in choosing ones that were high-sellers. Because our goal was to identify the various types of features and the range of them, and not make quantitative assessments about their frequency of occurrence in today's products, it was not necessary to bring any statistical approach to the effort, and in any case, our sample sizes would have been too small to draw quantitative conclusions.

As described in the ACEEE paper, there are three types of A/V devices: sources, intermediates, and sinks[2]. The most common sink is a TV and the most common intermediate is an A/V Receiver; there are a variety of sources, such as Blu-ray or DVD players, set-top boxes, and game consoles. The characteristics of each of these groups is substantially different so we treat them individually below after reviewing some overall patterns.

Also notable is that there are two basic topologies to A/V systems in U.S. houses: with, and without, an receiver. Without an receiver, each source device is connected directly to the TV, which is used to select among them. With an receiver, most or all sources are connected to the receiver, with a single connection from the receiver to the TV. A principal reason to have an receiver is to power speaker systems that are higher quality and provide surround-sound with many speakers rather than the two relatively small speakers that are inside each TV. If you want more than a basic TV experience, the receiver is needed. Related to this, there is the

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[1] Nordman, Bruce, *Audio/Video Inter-Device Power Control*, ACEEE Summer Study on Energy Efficiency in Buildings, August 2012.

[2] There are a few devices that can serve different roles at different times, and A/V receivers are intermediates for video but sinks for audio. We can put aside these issues for the moment.

question of getting high-definition (HD) video content to a TV to get the benefits of the higher quality picture this enables. Broadcast TV is now HD, but for other sources, this means a digital interface, nearly always HDMI[3]. For analog transmission, households usually use composite video, which cannot do HD. In addition, HDMI is much more commonly provided as an output for HD signals. Thus, moving to a higher-end experience leads to using and receiver and using HDMI, so this is a common deployment. For more basic TV, with primarily or only standard definition (SD) sources (e.g. DVDs rather than Blu-Ray disks and a SD set-top box), and using the TV speakers, no receiver is needed and standard composite video is sufficient. This is also a common deployment. The ACEEE paper shows a diagram of each of these.

In our assessments of devices in the field, we almost always found that people had devices of many different manufacturers. People do not seem obligated to stick with one manufacturer when they replace a device, and really should not. This makes proprietary technologies which require such brand allegiance unlikely to be very useful in practice.

This memo covers power modes, and controls that affect power state, all for the devices that we found. Since we are mostly talking about these devices, the language can seem awkward at times.

Modes

We are interested in basic "power states" of devices. While devices often have many different functional states within the on mode (and sometimes different states within a single low-power mode), annual energy use of these devices is predominantly a function of the fraction of time spent in each major power state. Devices range from having one to three basic power modes, plus the possibility of physically disconnecting it from power; the "disconnected" mode is not commonly used by consumers so not of great interest to this project. In past decades, it was fairly common to find receivers that had power outlets on the back, either switch outlets (disconnected when the receiver was powered down), or unswitched, but this is no longer common. Some manufacturers recommend unplugging the device if it won't be used for a long period of time. This saves energy, as well as protects it from surges on the electric line, including from lightning.

Some devices are always fully on when plugged in, such as some sub-woofers and some set-top boxes. These have no power control at all.

Low-power modes can be divided into two categories based on how the device can exit the mode to become fully on. We use "off" in this memo to mean a mode that can only be exited by a power control. A power control can be a mechanical switch on the device, on the remote control shipped with the device, a remote control shipped with another device, or a power command sent over another communications interface[4]. A timer to power on the device at a particular time of day also is allowed within our "off" mode definition. A device that can power up for any other reason is deemed to be "asleep". Some devices have just off or sleep, and some have both.

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[3] Technically a component video interface can support HD signals, but at these are rarely used, they don't enter the HDMI decision particularly.

[4] How much network connectivity should be considered within the scope of off may need to be revisited at some point.

Audio/video devices are not at all consistent with each other in how these modes are named. An off mode is commonly called off, standby, or both in the user manual. For example, we found a number of devices where the manual included language such as "the receiver will turn off (enter standby mode)". Some manuals use both terms on different pages. Sleep modes are commonly called standby, and sometimes off (and even occasionally Sleep).

Some devices have two off modes, with the major distinction in how fast the device powers up. In one case, the device has to go through a lengthy boot-up sequence, e.g. 30 seconds, which is not acceptable for most users. The second mode is internally a sleep mode, and enables a quick wakeup, but without any additional communications enabled (and so from the user perspective still an off). We can expect this second category of off modes to commonly gain more communications ability and so become a true sleep mode by our definition.

Source devices typically are the simplest in the number of power modes, with intermediates the most complex.

A key goal of this project is to move A/V devices away from "standby" and to the 3-state power model based on the sleep metaphor.

Control Mechanisms

This section reviews the various fundamental mechanisms that can change the power state of a device. Few if any devices have all of these; most have several. We review characteristics of each mechanism, its importance to the topic of power control, and limitations or future directions for it.

Power plug

Removing power from the device, "disconnecting" it, is the most basic way to control power state. Few people will want to do this regularly, so this is most used when the device is plugged into a power strip, timer, or a second device with a switched outlet. As devices get more communications and want to be asleep rather than off more of the time, actually removing power becomes problematic. Few A/V devices have batteries to power them between connection to the mains as notebook computers have.

Power switch/button

Most devices have a switch or button on the front, back, or side of the unit to change the power state. A few are rocker switches with explicit on and off states, but most are momentary contact switches to toggle between states. There is then commonly an indicator for the power state, often adjacent to the switch. Occasionally these are "hard" switches that cut power consumption to zero, but more commonly the devices still consume some power when off (a "soft" power switch), though often the amount consumed is usually small. The most common labeling of these is with the Power symbol  or the word "Power". A common variant is "On/ Standby" or  , or "On/off" or "Power - On/off". These switches and those on remote controls are the most important mechanisms today to change power state. Some manufacturers have a second hard power switch on the back, often only on models for certain markets like Europe and usually not on models for North America.

Remote control power button

Most remote controls includes one or two power buttons, usually at the top of the unit. When two, one is for the device it was shipped with, and the second for another device the remote is used to control. This second device is usually selected with a series of buttons or a selector switch. An example label for this second power button is "A/V |/⏻". Thus, in most A/V setups, more than one remote control can power up or down each device. A few remote controls include separate on and off buttons rather than a single power button that toggles the power state. Set-top box remotes can often control the power state of the TV and receiver, even if the STB itself does not power down when not in use.

Interface based

Some devices take the presence or absence of data on a communications line as a factor in determining when to power up or down. A simple example is a subwoofer which goes to sleep when the audio input line ceases to have sound to amplify, and then awakens when the input reappears. We expect that behaviors dependent on the presence of signals on interfaces will be increasingly important in the future.

HDMI/CEC

The CEC (Consumer Electronics Control) portion of the HDMI interface includes the capability of one device to send a power command to a second device. Not all HDMI interfaces and products implement CEC, so this is a potential mechanism, not guaranteed. In addition, the characteristics of data on any interface (most notably absence of data) can inform a device's internal decision-making. Manufacturers all have their own "branding" for CEC, partly since the different implementations are often not compatible. Examples include LG ("SIMPLINK"), Onkyo ("RIHD"-said to be compatible with Panasonic), Sony ("BRA/VIA Sync"), Panasonic ("Viera").

RS-232

For many years, some high-end devices have included a standard serial connection to enable external control devices (usually custom-made) to direct the operation of the device. RS-232 is the most commonly implemented of these. Each device specifies the commands it can accept over this interface, though presumably each manufacturer mostly re-uses commands from one model to the next. One device noted that its power state could be queried via RS-232 (implying it operates when the device is off), and sends out notices when it changes its power state. RS-232 commands will likely be replaced by IP-based (Internet Protocol) mechanisms.

Proprietary

Some communications links use a technology specific to an individual manufacturer (or just a few). The details of the communication across these is generally not public. Onkyo calls their interface "RI" (not to be confused with RIHD which is their name for their version of HDMI/CEC). Some devices enable direct connection of iPods and related devices, and while this is implemented by many companies, the interface specification is controlled by Apple alone. Some receivers can be set to power up when an iPod is put into an attached doc, or when Play is pressed on an iPod previously present.

Sleep Timer

Many TVs and receivers have a "Sleep timer", which refers to the unit powering down (to sleep

or off) when the user is expected to have gone to sleep. These commonly can be set to ranges up to 1 or 2 hours, in steps of 10 or 30 minutes. There may be a button on the front panel, on the remote, and may be an indicator light for this on the front panel.
At least one device we found had buttons on the remote for “On”, “Standby”, and “Sleep”, with the first two referring to power modes and the latter to the timer function. Using sleep for the low power mode could suggest changing the “standby” button to “sleep”, necessitating changing the label of the sleep button, but there are a variety of reasonable solutions to this. The name of the Sleep Timer function in general is not a problem as it could be changed to refer to the device going to sleep, not the person (assuming it goes to sleep and not off).

Other Timers

Some power control is determined solely within a device, e.g. with a timer from no user input, or after an activity is finished (e.g. a DVD ends).

Internet Protocol (IP)

While many A/V devices today have IP connections over Ethernet or Wi-Fi, all of the examples we examined to date were only for communicating to devices outside the A/V system, either on the Internet, or a PC on the local area network. These do not affect the power state of the device. Eventually we should expect use of IP connections between local A/V devices as a supplement to or replacement of HDMI, at which point the protocols on those connections would become critical to power control.

Menus

Some devices can be powered down by selecting this from an on-screen menu, an operation familiar with personal computers. As an example, the PS3 game console has this mechanism.

Most devices use more than one of these methods; some many.

Other relevant features

Some aspects of A/V devices are relevant to user experience or energy use, but not strictly about changing the power state.

Most devices have a power indicator (usually called that but occasionally “Standby indicator”); usually an LED that changes color based on the power state. These sometimes are used for other information, such as signaling an error condition, transitioning between power states (flashing), or user input (blinking when a remote key press was received).

There is an IEEE standard (1621) that addresses color coding for power indicators (development of this was PIER-funded). That uses green, yellow, and off, for respectively on, sleep, and off. A/V devices most commonly use red for on, and off for off. This likely dates from the time when only red LEDs were available (and they are still cheaper), but as red is supposed to mean an error or warning, this is not correct use according to indicator color standards. We found one device (a TV) which had an option to switch the use of the indicator to be on when the device was off, and off when it was on (presumably to not have the indicator be a distraction when watching it, and to show that the remote control is being listened to when it is off; this was called “Store Demo” mode). IEEE 1621 does speak to the usage model of keeping the indicator off when the device is on, but specifies that the color should then yellow for sleep to be consistent with other devices. On a display, the fact that the display is on is clear evidence that

the device is fully on. A game console manual cautions users not to move their device if it is on based on the condition of the power indicator (presumably so that it the disk is not jarred).

PS3 has the indicator red when off and green when on (and flashing green when it is in the process of turning off). Some projectors use flashing yellow for powering down and flashing green to indicate powering up; that is, they flash in the color of the state they are moving to.

Power button uses

Sometimes the Power button is used for other purposes. On one STB, it is used to change the mode of the remote when programming it. On many devices, holding down the power button for an extended time will reboot and/or reset the device (PS3 normally requires 5 seconds after which it beeps twice; if it is frozen may require 15 seconds). Also on the PS3, the power button is disabled during a system software update. A receiver uses a 5-second press of the power button to reset the configuration settings of the device (the front panel declares “CLEARED!”). This same device will change several different settings if a particular second button is held down while the machine is powered up with the power button.

Brightness

Reducing the brightness of a TV reduces the power consumption level. This can be done manually, or automatically, based on ambient light levels. Energy Star calls this Automatic Brightness Control (ABC). One manufacturer calls this an “Intelligent Sensor”, and also had an “Energy Saving” button on the remote for reducing brightness. It also had options for what this does listed as “Off, Minimum, Medium, Maximum, Auto, Screen-Off”.

Internet Protocol (IP)

Many device types can download video or audio-only content from the Internet, including Internet STBs, satellite STBs, game consoles, some Blu-Ray players, and some receivers. Ethernet is commonly used by game consoles to download games, to obtain firmware updates, or to use for multi-player games. For this, they

With several Ethernet-connected devices in an A/V rack, it can be simplest to have a local Ethernet switch to be able to run one wire from the rack to the rest of the network rather than many cables. This switch is not part of the A/V system by our definition, but in this case is really associated with it. Network equipment does not have low-power modes and for practical purposes needs to be left on all the time, since sometimes it is accessed asynchronously from the user’s use of the system. Note that to date, Ethernet is rarely if ever used to move content between A/V devices in a local system, but rather to acquire content from elsewhere on the local network or Internet (e.g. a PC or paid content provider) or to gather other useful data; we expect this to change.

Remote Control codes

While it would make a lot of sense for all remote controls to send the same code for the same named button, there is no standard translation from remote control names to numbers (as we have with the ASCII character set in which “A” is 65, “B” is 66, etc.). The consumer electronics industry failed to do this as manufacturers worried that such interoperability would undermine their brand identity. Some user manuals include these encodings.

It is common for remote control command sets to include both a “Power” command which toggles the power state, and deterministic “Power On” and “Power Off” commands (for three

separate codes). Remote controls can often be programmed to implement different command sets; on some devices this is made easier when the whole device is connected to the Internet.

Front panels

More and more devices have some or all of their user interface put onto the TV display so that they have less need for a lit front panel that shows system status. As these displays can be distracting, some devices allow it to be dimmed or turned off entirely. This may have a small power benefit. A lit front panel display is usually another indication that the device is fully on, though the power indicator should also be present.

Device-specific notes

This section presents findings that derive from characteristics of individual devices.

Capabilities in "Off"

A DVR we found labels its low-power mode "off" but can both record shows and "receive messages" in this state. Most media sources (e.g. DVD or Blu-Ray players) remember the place where they were paused or stopped through an on/off cycle, some with a limit (e.g. 5) of the number of disks they remember the locations for.

A satellite STB only updates software when the system is Off, so that the manual encourages this (the manual also mentions that guide data is downloaded in off, but presumably that also occurs when the device is on).

Powering down

Many source devices deliver their content in finite streams, such as movies on DVDs or Blu-Ray disks, or recorded content. Once done, a navigation menu is typically displayed. While some devices leave this up indefinitely, others can put up a "screen saver" (a moving image to avoid 'burn in' with particular display technologies) or blank the signal entirely. One Blu-Ray player went out of navigation mode after three minutes to either a screen saver or an "energy saver" function which turned off the video. Some devices take some time to power down and should not be removed from power before completing; an example is projectors which run the fan to cool the lamp to extend lamp life. One receiver has a second way to use the sleep timer to set a time of day (in 30 minute increments) that it should power down at.

Powering up

While most remote controls only power up the device with a power button, a Blu-Ray player would do so on any press of the remote.

CEC details

Most devices that support HDMI/CEC allow it to be disabled. A Blu-Ray player with two HDMI outputs allowed this to be different between the two, and also to enable only a subset of commands to operate, such as disabling power commands. On a receiver, CEC needs to be enabled to use the Audio Return channel no the HDMI link, so that functional use of the link is dependent on CEC enabling.

For HDMI/CEC to operate, all relevant devices need to have it enabled and need to interact with each other to discover this fact. This is not automatic, and the particular sequence of operations

needed to accomplish it vary by device and manufacturer. This is an impediment to wide use of the feature.

CEC features include some like “One-Touch Play” that automatically power up devices (including the TV and Receiver) when a play function is initiated. There is also a “System Power Off” function that powers down all devices when the TV powers down (though this implicitly assumes that the receiver will not be wanted for a non-TV purpose like listening to the radio). The manual for the receiver has the note: “Set the TV power supply interlock function to ‘ON’ before using the System Power-Off function” -- whatever that means.

Audio-only modes

There are many reasons that people may listen to, but not watch, their A/V system. It may be being used for audio-only content (e.g. a CD or radio), content with limited video interest (some concerts, or a display of radio artist/title information), or when a person is in another room but following the activity by the audio (e.g. some sports events).

A receiver had a “Music” option on the remote which would then not power up the TV as all other major options would do. A Blu-Ray player has a “Pure Audio” mode that disables internal video processing so as not to introduce any artifacts into the audio signal. That said, the manual states that HDMI requires that a video signal be transmitted (even when only audio is being use) so that a black screen is sent across the wire.

Auto Power Down

The Energy Star specification for A/V devices has a requirement for Auto Power Down for several A/V device types. This conveniently avoids deciding whether it is to Sleep or Off. A receiver can do this after 30 minutes of both no user activity and no audio or video signal input[5], though curiously the as-shipped setting was to have the feature enabled for Europe, Australia, and Asia, but disabled in North America and Taiwan (Taiwan uses 115 VAC like North America which may explain this).

The PS3 has a “System Auto-Off” function that can be off, or have a timer of 1, 2, 3, or 5 hours. This doesn’t engage during gameplay or media playback, though a separate flag can be set to do this as well called “Turn Off System Automatically Even Under Special Conditions”.

A receiver describes how it selects the audio channel to use, in a particular priority, depending on which signals are actually present. Analog is the last. Ability to detect this for functional purposes means that it would be possible to use that information for power control purposes.

Increasing low-power mode power levels

User manuals sometimes note factors which raise the power consumption of the device when asleep or off above the minimum level. A receiver does this when the power part of HDMI/CEC is enabled (as when enabled, circuitry needs to monitor content coming over the CEC line). This also enables “HDMI pass-through”, which allows HDMI signals from an input line to flow through to the output even if the device is powered down. On one receiver, there is an option to do this always, or only when the TV is powered on (and of course, this detection might only

[5] Ominously, the manual for this device says “depending on some sources, he auto power-down function may activate during playback”. No further information is given, but this could be a reason for people to then disable the feature entirely.

work if you use the same brand of manufacturer to have compatible CEC implementations); this reduces the power used by the receiver when the TV is off. When the receiver is in this mode, it displays a notice “A. STANDBY” when the data signals are being passed and the coordination with the TV is working.

Error conditions

On the PS3, if it is too hot, it will refuse to turn on, and “beep repeatedly” before it turns off. If it is on and gets hot, the power indicator will alternately flash red and green.

Zone 2

Some receivers can send audio output to a second zone, elsewhere in the building, either the same content as the main speakers are getting, or content from a different input to the receiver. Some receivers have an input for a remote IR receiver (a wire connects the two) to enable a remote control in a different room to control the receiver, and some have an output on the back to send IR commands a remote second receiver through the same interface type (that is, the receiver is effectively simulating a remote control). While this can certainly be made to work with enough remote controls, correct programming, and the right number of IR receivers, it does seem as though it could easily be confusing to the user as there are then two of each of many device types that are interconnected. Zone 2 outputs are typically analog and so cannot route HDMI content. Some devices have a Sleep Timer for Zone 2 separate from the main one.

Controlling multiple devices simultaneously

Some people we interviewed expressed a desire for auto-off functionality, in case they forget to power the system down manually, or if it is used by someone not totally familiar with how the system works.

On one receiver remote, pressing both of the available power buttons at the same time powers down all devices on the system (including those in Zone 2), not just the two being addressed.

The PS3 game console has a “PS” button on its remote that can turn the system “on/off”. Turning off requires pressing it for more than a second as well as confirming with a query displayed on the screen.

Due to copy protection concerns, video coming in through an HDMI connection is not output to non-HDMI interfaces. This has the effect of requiring use of HDMI to the TV from a receiver if any of the receiver’s inputs are HDMI, further cementing its importance as an interface. We can expect that the HDCP copy protection scheme in HDMI will eventually be extended to other interfaces (for example, HDBaseT, an emerging Ethernet-based interface, uses HDCP), but this may be slow. Non-HDMI inputs can be moved to HDMI, since that does not introduce copy protection concerns.

Some information in CE device manuals is cryptic, and defies easy understanding; see for example, the following excerpt from the Denon 1712 Receiver manual.

Setting items	Setting details
Standby Source Sets the HDMI input source to put into standby when the power is on.	**Last** : This item is set at the last-used input source. **HDMI1** / **HDMI2** / **HDMI3** / **HDMI4** / **HDMI5** / **HDMI6** : Put the respective input source into standby. "Standby Source" can be set when "HDMI Control" is set to "ON".

Other Devices

HDMI Switches

Device software updates often require manual or automatic cycling of the power state of the system to reboot the system, though this has no particular bearing on total energy use.

Conclusions

The wide use of HDMI as an interconnect seems destined to increase, though at some point there will likely be a standard (hopefully only one) way to transmit such data from device to device over Internet Protocol (IP) via Ethernet or Wi-Fi. People will increasingly have and want HD content, and manufacturers will increasingly leave off analog connections entirely (some do already).

Manuals make clear that there are complexities to use of HDMI that make clean interoperability

For next steps, the capabilities described above will help in crafting use cases and possible approaches to making power control automatic. In many cases, a new system will need to both coexist with existing capabilities, and as feasible, absorb legacy mechanisms into the new one.

Scope descriptions:
1) Assess existing products and usage by surveying products in use in buildings, on sale in stores, and available on-line, with a focus on the connections between devices.
2) Prepare an Existing Product Assessment and Conclusions Memorandum that summarizes the findings from the existing product assessment and makes key conclusions regarding the implications of the findings with regard to saving energy.